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REDUNDANT SENSORIZED ARM+HAND SYSTEM FOR SPACE TELEROBOTIZED MANIPULATION

prof.Alberto Rovetta, eng. Paolo Cavestro

Department of Mechanics
Politecnico di Milano, Italy

Abstract

This paper deals with an integrated system, composed of an arm, a wrist, a mechanical multifingered hand, which has been realized in separate parts, and which is on development for possible application in telemanipulation.

The redundancy of the degrees of freedom of the system and of the sensors, the application of logical rules and the supervision of teleoperators may be applied in order to have an optimum of reliability of the system in space telemanipulations.

1.INTRODUCTION

This paper deals with the realization of a mechanical system, (indicated FCR8) for telemanipulation in the space (Fig.1).

Objects of generic shape, of relatively small and big sizes, of different masses and deformabilities, may be manipulated and grasped by a robotized system, which is constituted by an arm (fig.2), a wrist and a multifingered hand (fig.3).

By means of a strict integration among the sensors data , the mechanical and electronic software for the control of hand and arm motion, is possible to perform a multipurpose task in the space.

The redundancy of the system may be utilized to different goals, with specific reference to the telemanipulation.

The recognition in the space application is performed by the hand itself, which touches the object and determines parameters for the optimization of the prehension configuration.

After the recognition phase, the hand is moved to the final manipulation, also with the support of the teleoperator.

A parallel process of simulation and modelization, also with the aid of expert systems, may be performed.

The feasibility project is reported, for the first laboratory prototype.

2.USE OF BASIC PRINCIPLES OF TELEOPERATIONS IN THE DESIGN OF THE MANIPULATION SYSTEM

The basic principles of teleoperations in space, adopted in the development of the feasibility project of the mechanical system FCR8, are reported.

They are:

- internal functionality of the hand, with its own capabilities in the prehension of objects, according to physical principles;
- redundancy of informations and data from the sensors and communications channels from the hand, from the arm and from the environment towards the operator, with the evaluation in every moment of the reliability of every signal and data;
- teleoperations in macrooperations and in microoperations, with different ranges of tolerances and precision, with the supervision of the whole process by a second operator, able to assist the general process, instead of the single phases, and in every case to assist the main operator.

The concept of a double teleoperation is devoted to the redundancy of control, in order to obtain a local intelligent control by one operator, and a whole supervision, during the process, and in the same time with the aims of serving an emergency recovery, in front of unforeseen events.

Reliability in teleoperations and telemanipulations in the space is the main fact in front of the evaluation of the quality of the work in the space.

3.MANIPULATION SYSTEM DESCRIPTION

The manipulation system is composed of a mechanical hand, with three fingers and a palm, (see References /1/), connected to a supporting system, with 6 degrees of freedom.

The hand performs the manipulation process, grasping the elements and moving the single fingers in order to perform the task.

The mechanical system, which supports the hand, presents six degree of freedom in the motion.

It is similar to a robot, where the arm presents 4 degrees of freedom, and the extremity part, analogue to a wrist, presents two degrees of freedom.

The total system presents six degrees of freedom in the support structure and 13 degrees of freedom in the hand.

The strategy of the control system is that the redundancy of the degrees of freedom is fundamental to obtain a manipulation process which offers reliability.

4.DESIGN OF THE SUBSYSTEMS

The design of the hand is obtained with reference to some basic principles, connected with mechanical and systems laws.

Some of these principles are:

use of three fingers and one palm, to obtain a multiple points contact, to ensure a reliable prehension; use of friction surfaces for the fingers and of smooth surfaces for the palm, to increase prehension stability; use of a settlement phase, able to obtain a sequence of micromotions of the object in the hand, which perform the process of selfadjustment of the object inside the hand; integration of sensors data, by using the redundancy of the sensors output signals for improving the reliability and capability of the control system; development of different parallel sensors, for the control of the prehension process itself.

The design of the arm which supports the hand is developed in order to offer to the hand a support of 6 degrees of freedom, which may be controlled in a parallel way.

5.CHARACTERS OF THE TELEROBOTIZATION

The manipulation process may be subdivided in different phases, both in time and in space.

The first phase is the approach phase, where the manipulation system is moved in order to approach the objects to be manipulated, inside a certain operative radius in the working area.

The mechanical arm and the wrist must be moved in order to get a position, with a large capability of motion and operation.

The control of the motion is obtained according to the rules of the expert systems, in order to have a collision avoidance and a optimal trajectory choice, also considering the reliability of the system.

(The methodology of the expert system application for collision avoidance and optimal trajectory choice has been presented and developed in Ref. /2/.)

After the approach phase, the manipulation phase may begin.

It is subdivided in two parts: the first part is the operation of grasping of the object or of the tool, the second part is the motion of the object or of the tool.

The presence of a double arm may simplifie the procedure, in front of a better dexterity of the system.

In conclusion, the operations are a sequence of macrooperations and of microoperations, which are performed by the system.

The teleoperation is obtained by means of the choice of the strategies of approaches and of the tasks.

The tasks are subdivided in elementary tasks, and the elementary tasks, developed by the elements of the system, are supervised by the teleoperator.

Teleoperation in the system here presented consists in the subdivision of tasks in sub-task.

Teleoperator decides the subdivision of tasks, and the system operates freely inside the subtasks, according to simple boundary conditions or more complex expert systems rules.

The here described task has been under development, in different subsystems, in the Laboratory of Robotics, Department of Mechanics, Politecnico di Milano.

The process of interaction must be developed in the future according to the design rules, represented synthetically in Fig.4.

6. REQUIREMENTS FOR MANIPULATION IN THE SPACE

The FCR8 system presents some features for telemanipulation in the space.

They are mainly:

1) capability to approach the operating position, by the use of inverse kinematics, applied to the mechanical arm, with the choice of optimal trajectories, according to prerequired functions;

2) possibility of developing dynamic control with reliability evaluation of different functions, by the consideration of the reliability functions of the mechanical components (see Ref./3/);

3) adaptability of the hand to different functions, with the selfadjustable prehension and grasping phase, both for the single object or for a working tool;

4) sensitivity of the mechanical hand in front of dynamical perturbations, by means of the motion of the fingers, in order to obtain a stable prehension in grasping and a reliable gripper for the use of the tools;

5) reliability of the system , in front of a mechanical and electric design, which need no lubricant or liquid material, and which may be applied to loads of Nw up to hundred of Nw, with a selfadaptability of the prehension system.

The teleoperation may be performed by means of two levels:

- macrooperations
- microoperations.

The macrooperations may be performed with the support of the sensors which are in the system.

The operating sensors are : force sensors and tactile system in the hand for a first recognition of the unknown object to be grasped; vision and recognition system on the arm, able to determine the characters of the environment.

The integration of the sensors with the "experience" of the robotized system and of the teleoperator is a main character of the system on development.

Multiprocessor system and transputer system are on application for adapting the computers capabilities to the telerobotized system requirements.

7.CONCLUSIONS

An integrated system, composed with an arm, a wrist and a hand with redundancies in the mechanical design and in the sensors, may be used for telerobotics in space, where reliability of the system is a basic element.

The application in the space is indicated in front of different subtasks which may be performed by the robot.

Supervision in the steps of the tasks is obtained by the operator, where a second operator may evaluate the reliability of the single subtasks in front of the results.

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References

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/2/ A.Rovetta, R.Sala, Optimization of trajectories in assembly with logical support, Tecniche dell'Automazione, june 1988

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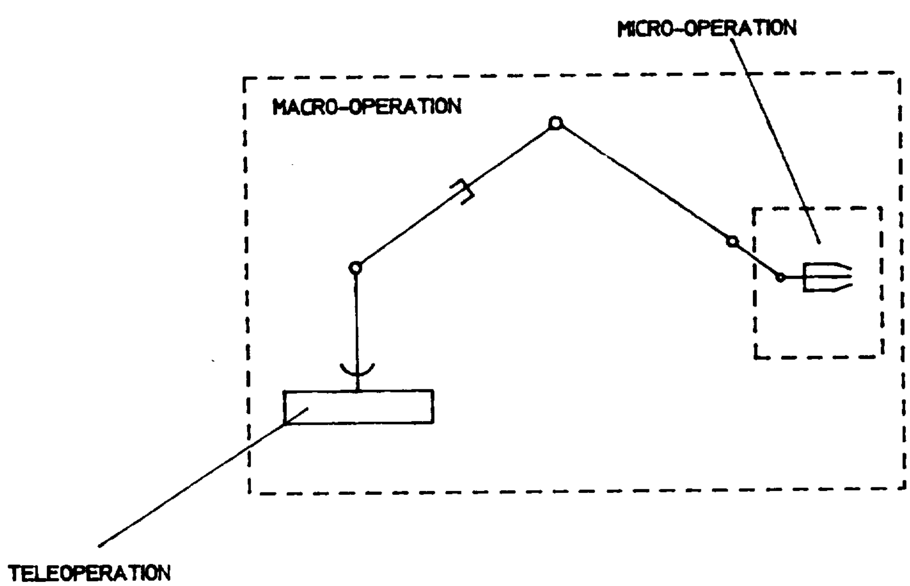

FIG.1 ARM+WRIST+HAND (6+13 DOF)

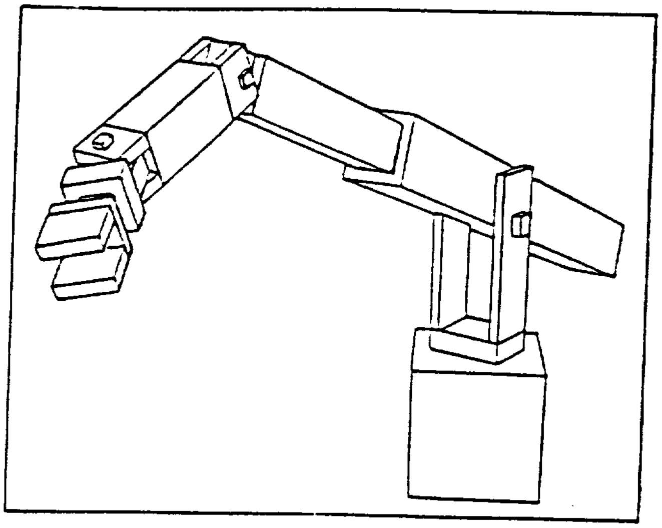

Fig. 2 Mechanical arm with 6 degrees of freedom

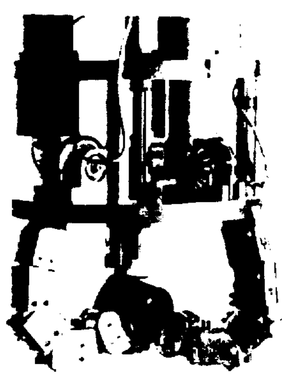

Fig. 3 Sensor controlled multifunctional robot hand

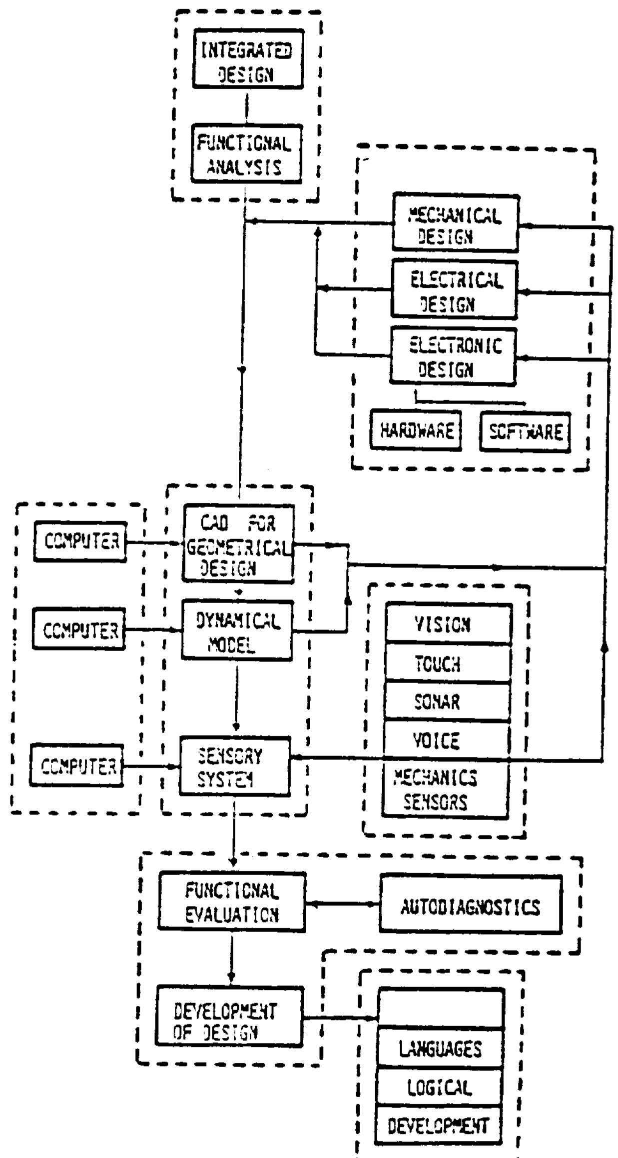

Fig. 4 Conceptual scheme for the system integration